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CONTENTS

WICOMICO SHORELINE IN ORANGEBURG, DORCHESTER, AND BERKELEY COUNTIES, SOUTH CAROLINA

By

D. J. Colquhoun 1/

INTRODUCTION

In February and March, 1961, investigations were made of deposits attributed by Cooke (1936, plate 7) to the Wicomico shoreline of Pleistocene age exposed in road cuts along highway I-26 in Orangeburg, Dorchester, and Berkeley Counties, South Carolina. The Wicomico shoreline apparently stood about 95-100 feet above present sea level. Fifteen selective samples were taken from road cuts at depths of 3-5' below the surface and processed for grain-size distribution at the University of South Carolina. Textural observations were noted. The preliminary results are herein reported, and are in general agreement with many other samples being processed at present; but environmental interpretations are regarded as only tentative.

PREVIOUS WORK

Sloan (1908, p. 481) appears to have recognized the presence of sand deposits ascribed in this paper to the 95 foot shoreline. Cooke (1936, pp. 143-147) admirably stated the position of the shoreline during this time and described stratigraphic sections at a number of localities. Flint (1940, pp. 758-770) summarized previous work published concerning Pleistocene features of the Atlantic Coastal Plain and accurately surmised that beach, lagoon, and sand bar deposits were present, although he did not illustrate the point through sedimentary analysis. Richards (1945, 1950, 1954, 1956, and 1959) described Pleistocene stratigraphy and paleontology in the Atlantic Coastal Plain and in adjacent states and outlined European correlations. MacNeil (1950) recognized similar sediments in Florida and distinguished between mainland and bar beaches. Doering (1960) well summarized Pleistocene sediments in South Carolina from a regional standpoint.

PHYSIOGRAPHY

The 95 foot Pleistocene shoreline is well exposed across the middle Coastal Plain of much of South Carolina, being little dissected by later erosion. Since it is nowhere covered by later deposits in the region examined, it lends itself easily to sedimentation studies. Sea-cliff, beach, lagoon, bar and shelf deposits are all excellently exposed,

1/ Department of Geology, University of South Carolina.

EASILY MAPPED, AND REMARKABLY PRESERVED (SEE FIG. 1). THE SEDIMENTS ARE UNCONSOLIDATED AND LITTLE ALTERED. THE SEA-CLIFF AND BAR DEPOSITS ARE COMMONLY WELL DRAINED, THE FORMER BY RUN-OFF THROUGH CHANGE IN ELEVATION, THE LATTER PROBABLY BY SUBSURFACE GROUND-WATER DRAINAGE. THE BEACH, LAGOON, AND SHELF AREAS ARE COMMONLY POORLY DRAINED AND SWAMPY.

SEA-CLIFF AND BAR LANDFORMS ARE FOUND AT ELEVATIONS OF 95 TO 105 FEET MEAN TIDE LEVEL, BEACH AND LAGOON LANDFORMS FROM 85 TO 95 FEET M.T.L., AND SHELF LANDFORMS AT ELEVATIONS OF LESS THAN 95 FEET.

SURFACE DRAINAGE ALONG THE SHORELINE IS OF TWO TYPES; THROUGH BEACH, LAGOON, AND BAR BELTS IN OLD ESTUARY AREAS ALONG THE MAJOR RIVER VALLEYS AS WELL AS MORE RECENT SMALLER TRIBUTARIES; AND PARALLEL TO THESE DEPOSITS PRINCIPALLY IN THE BEACH AND LAGOON AREAS AS WELL AS NEXT TO THE SHELF SIDE OF THE BARS.

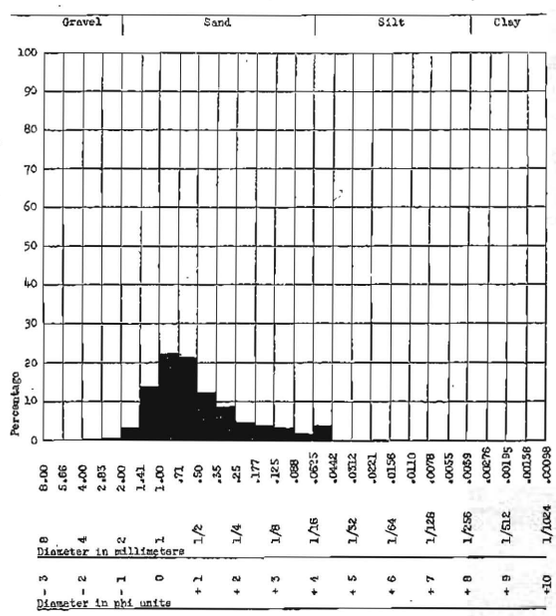
STRATIGRAPHY

DEPOSITS OF THE 95 FOOT SHORELINE HAVE BEEN TERMED THE WICOMICO FORMATION BY SHATTUCK (1901) AND LATER REDEFINED BY COOKE (1930). THE LATTER STATES THEY CONSIST "CHIEFLY OF FINE SAND BUT INCLUDE SOME CLAY, COARSE SAND AND GRAVEL". "THE DEPOSITS FORMED IN ESTUARIES TEND TO BE COARSER GRAINED THAN THOSE LAID DOWN IN THE OPEN SEA AND CONTAIN MORE GRAVEL. THE FORMATION IS NOWHERE VERY THICK. IT PROBABLY EXCEEDS FIFTY FEET IN THICKNESS AT FEW PLACES AND MAY AVERAGE LESS THAN 25 FEET." IT IS UNDERLAIN BY THE HAWTHORNE FORMATION, RAYSOR MARL, DUPLIN MARL, PEEDEE FORMATION, BLACK CREEK FORMATION (COOKE, 1936 PP. 143-147) AND THE COOPER MARL AND OTHER UNITS. IT VARIES FROM 0 FEET IN THICKNESS IN THE WESTERN SEA-CLIFF AREA TO A MAXIMUM OF 40-50 FEET IN THICKNESS IN SOME PORTIONS OF THE SAND BAR FACIES. IT IS LEAST THICK IN THE MAINLAND BEACH FACIES, PROGRESSIVELY THICKER EASTWARD IN THE LAGOON FACIES, AND INTERMEDIATE IN THICKNESS IN THE SHELF FACIES, ALL THICKNESSES OF COURSE BEING CORRECTED FOR RECENT EROSION.

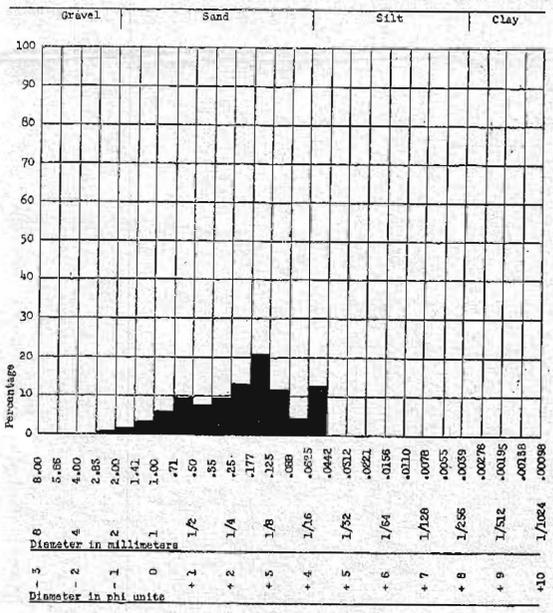
THE EASTWARD LIMIT OF THE SHELF FACIES IS AT PRESENT INDEFINITE. THERE IS PRESENT ON THE TOPOGRAPHIC MAPS AN ABRUPT CHANGE IN ELEVATION FROM APPROXIMATELY 70 FEET TO 30 FEET, AND IT MAY BE THAT A SUBSEQUENT SHORELINE HAS DESTROYED MOST OF THE APPARENT SHELF FACIES. ONLY MORE FIELD WORK WILL CLARIFY THIS FEATURE.

SEDIMENTARY PETROLOGY

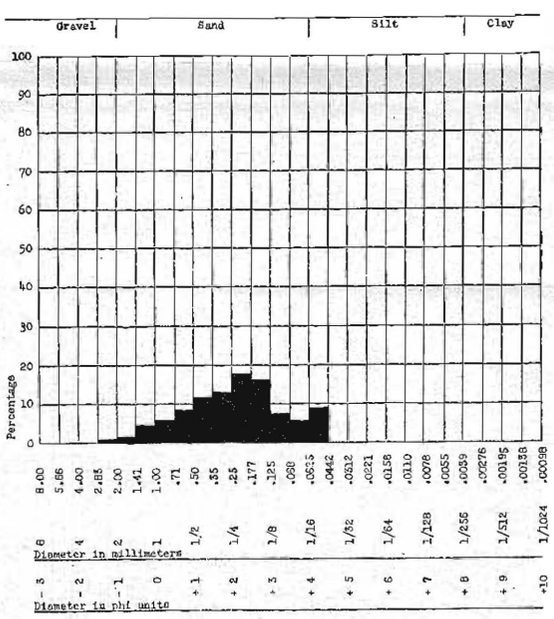
GRAIN SIZE: - FROM DATA COLLECTED TO DATE THERE APPEAR



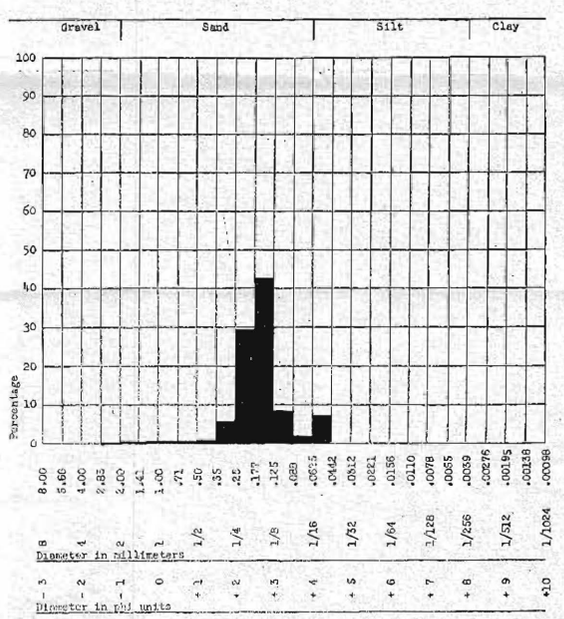
BEACH



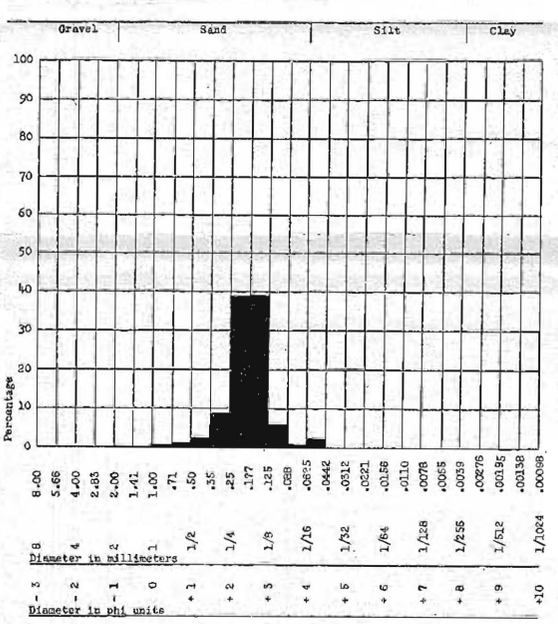
BEACH - LAGOON



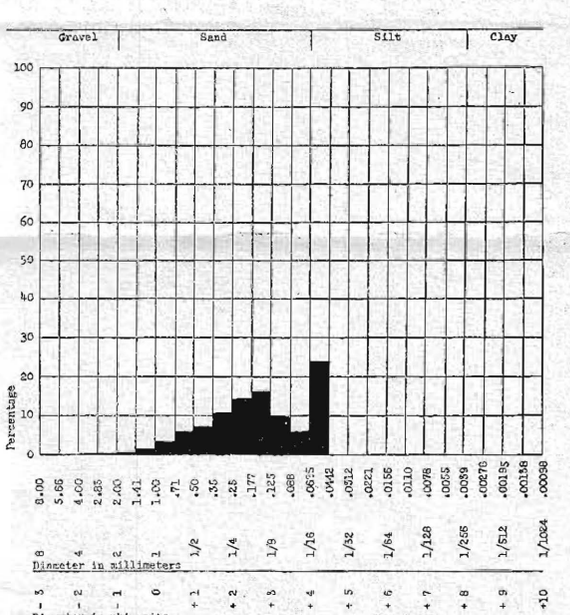
LAGOON



LAGOON - BAR



BAR - DUNE



SHELF

Fig. 2. Grain size distribution of Wicomico deposits- Orangeburg, Dorchester, and Berkeley Counties, S. C.

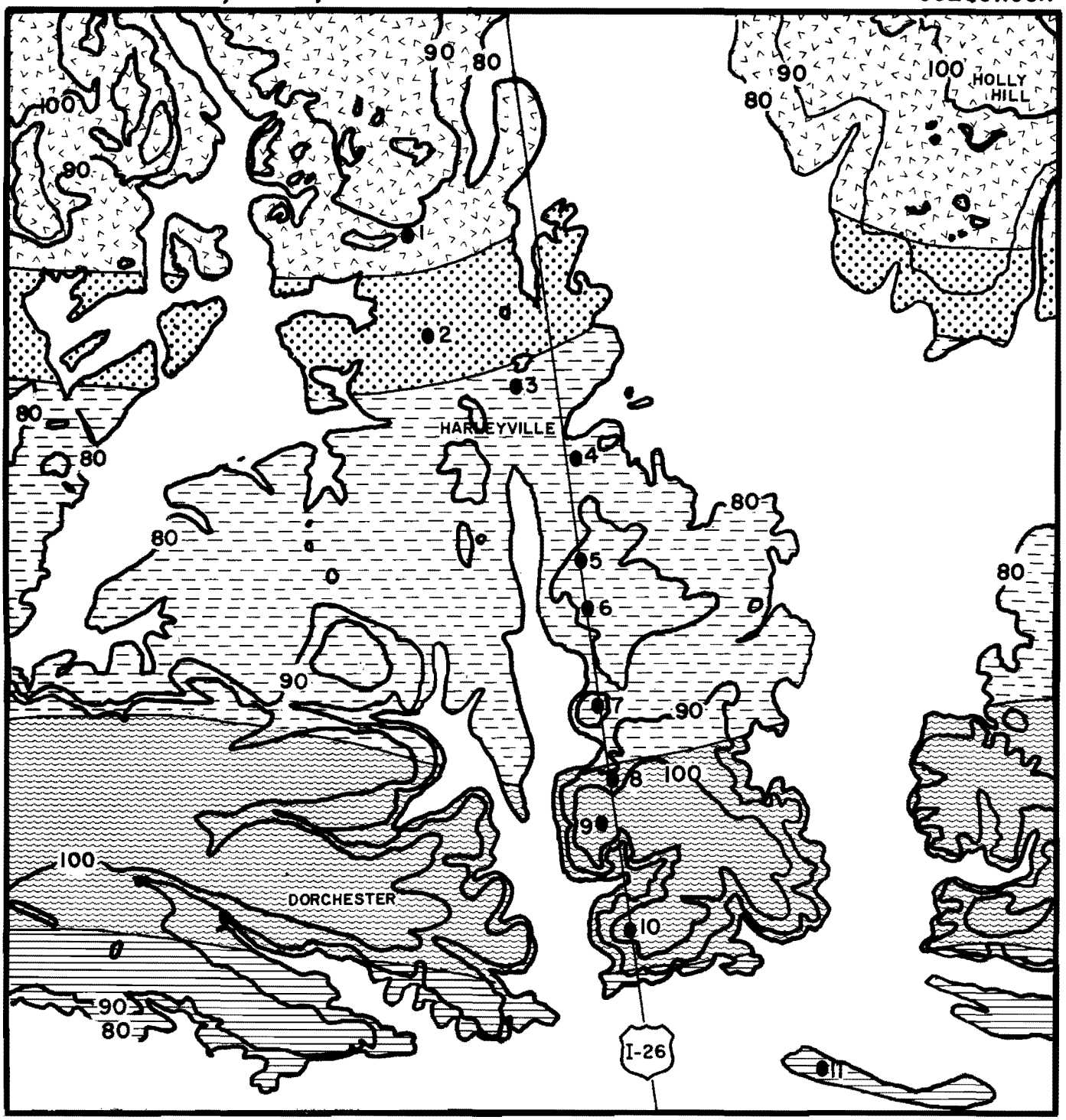


Fig. 1. Wicomico shoreline (Pleistocene) deposits in part of South Carolina.

TO BE TWO MAXIMA PRESENT WITHIN TOTAL GRAIN SIZE DISTRIBUTION, 1.00 TO 0.50 MMS., AND 0.177 TO 0.125 MMS. MAJOR CHANGES IN MEAN PARTICLE SIZE APPEAR TO BE DUE TO MIXTURES OF THESE GRADES, IN SIGNIFICANT PART THROUGH PROVENANCE. MINOR CHANGES IN PARTICLE SIZE ARE DUE TO ENVIRONMENTAL DIFFERENCES THROUGH SELECTIVE TRANSPORTATION AND DEPOSITION WITHIN THE PARTICULAR ENVIRONMENT.

GRAIN TEXTURE: - VISUAL OBSERVATION INDICATES THAT MOST OF THE COMPONENTS ARE EXTREMELY IMMATURE TEXTURALLY EVEN IN THE COARSER SIZE FRACTIONS. SPHERICITIES ARE RELATIVELY HIGH RANGING FROM 0.81 UPWARD, BUT ROUNDNESS IS EXTREMELY LOW VARYING FROM 0.3 TO 0.1 FOR MOST OF THE COARSER SIZE FRACTIONS, AND 0.1 TO 0.2 FOR THE FINER SIZES. LOWER SPHERICITIES HAVE BEEN NOTED FOR THE FINER FRACTIONS.

GRAIN MINERALOGY: - AS YET THE SEDIMENTARY PETROLOGY LABORATORY AT THE UNIVERSITY OF SOUTH CAROLINA HAS NOT MADE MINERALOGY RUNS IN CONNECTION WITH THIS PROJECT, BUT THEY WILL BE COMMENCED SHORTLY.

GRAIN SIZE DISTRIBUTION: - DATA CONCERNING THE SPATIAL RELATIONS OF GRAIN SIZE DISTRIBUTION ARE INDICATED IN FIGURE 2.

BEACH FACIES

BY VOLUME, BEACH SEDIMENTS COMPRISE ONLY ABOUT 0.04% OF THE TOTAL BEACH, LAGOON AND BAR SEDIMENTARY UNITS; BUT IN AREAL EXTENT THEY COMPRISE 16.2%. MAXIMUM GRADE SIZES RANGE FROM 1.00 MMS. TO 0.50 MMS. WITH THE MOST ABUNDANT GRADE OCCURRING AT 0.71 MMS. THE GRAINS ARE MOSTLY QUARTZ FROM VISUAL OBSERVATION, HAVE A SPHERICITY OF 0.85 ON THE AVERAGE AND A ROUNDNESS OF ABOUT 0.3. SORTING RANGES FROM 1.4 TO 1.7; SKEWNESS FROM 4.5 PLUS TO 2.0. THE CLAY CONTENT RANGES FROM 0.00 IN THE UPPER BEACH TO ABOUT 6.00% IN THE LOWER. CLAY MAY BE INTRODUCED THROUGH SHEETWASH AND DECOMPOSITION TO SOME EXTENT. ABOUT 77% OF THE MATERIAL LIES WITHIN THE THREE MAXIMUM SIZE GRADES IN THE SAMPLES EXAMINED. DECREASE IN MEAN SIZE NOTED IN FIGURE 2 IS DUE TO ADMIXTURE OF A FINER SIZE SEDIMENT IN THE 0.177 MM. GRADE AND CLAY IN THE LOWER BEACH, AND NOT TO A DECREASE IN MEAN SAND SIZE. THE UPPER BEACH NEXT TO THE SEA-CLIFF HAS TO SOME EXTENT SUFFERED MASS-WASTING THROUGH CREEP SO THAT THE SUBSTRATUM (DOERING'S SUNDERLAND FORMATION) IS NOW MORE EXPOSED EASTWARD THAN IT WAS ORIGINALLY. IN THE CROSS-SECTION STUDIED, BEACH SEDIMENTS OCCURRED OVER THE FIRST 1.75 MILES EAST OF THE SEA CLIFF. KURTOSIS VALUES ARE IN EXCESS OF 2.0. (WHERE QUOTED, MEAN SIZE (M), SORTING COEFFICIENT (So), SKEWNESS COEFFICIENT (Sk) AND KURTOSIS COEFFICIENT (K) ARE CALCULATED AS IN PETTIJOHN, 1957, P. 36). FIGURE 3 SHOWS SEDIMENTARY PARAMETERS FOR THE BEACH, LAGOON, BAR, AND SHELF FACIES.

Lagoon Facies

By volume, lagoon sediments comprize about 28% of the total beach lagoon and bar sedimentary unit; but in areal extent they occur over 43% of the area from sea-cliff to the east edge of the bar. Maximum grade sizes found are from 1.00 to 0.50 mms. toward the beach, decreasing to 0.177 and 0.125 toward the bar. It is a region therefore of mixing between the two dominant sand grades. Figure 2 illustrates the decreasing nature of the mean grain size, but should be regarded as a decrease in the coarser and an increase in the finer size toward the east. Roundness and sphericity determinations are similar to those noted in the beach facies. Proceeding from west (beachward) to east (barward) the sorting value rises from 1.7 to a maximum of 1.8 to the west of the middle of the lagoon then decreases to 1.1 adjacent to the bar. The skewness decreases from 2.0 to 0.8 then rises to 1.0. The kurtosis in general decreases from about 2.0 to 1.135 from the west toward the east, and lies flat in the western third of the lagoon at 2.0. Clay content rises from 7% in the west to 13% in the mid lagoon then falls to about 6% adjacent to the bar. After a decrease to 38% in the eastern portion, the percent sand in the maximum three grades rises to about 80% adjacent to the bar. In the cross-section studied, lagoon sediments were spread over a five mile wide belt parallel to the shoreline.

Bar Facies

By volume, bar sediments comprise about 72% of the beach, lagoon, and bar sedimentary units; but areally they comprise about 41%. The bar sediments represent the most constant of the three environments of deposition with regard to the measurements reported. Mean size varies from 0.125 to 0.225, rising and falling directly with the topographic profile. Sorting also follows this pattern, being about 1.1 in the west, rising to 1.25 just in advance of the topographic high, and falling to about 1.05 in the east only to rise slightly just before the shelf environment.

Skewness is practically constant at 1.0, varying hardly at all. Clay percentage decreases from about 5% in the west to a minimum of 2% east of the bar's topographic high to increase again to about 3% on entering the shelf. Kurtosis "bells" up slightly about 0.1 to 0.2 in response to the topographic high. Percent sediment in the maximum three grades stays high and slightly increases eastward from 80% to a maximum of about 86%. In cross-section, bar sediments spread over a belt about 4 miles wide perpendicular to the shoreline.

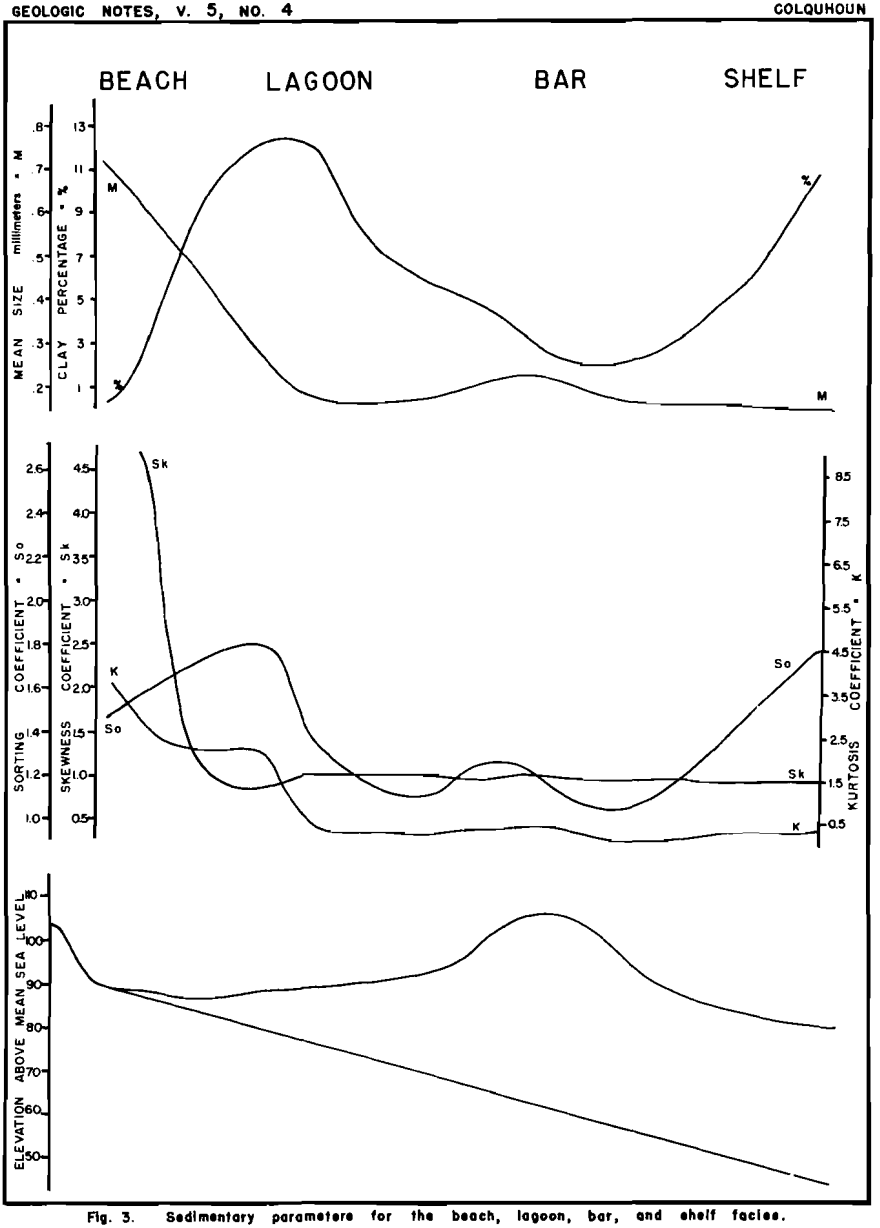


Fig. 3. Sedimentary parameters for the beach, lagoon, bar, and shelf facies.

Shelf Environment

Too few samples have yet been studied to make any direct observations here. Eastward from the bar, the mean size decreases, the sorting coefficient increases, the skewness coefficient is constant, the kurtosis coefficient decreases or is constant, percent clay increases, and percent sediment in maximum three grades decreases.

PROVENANCE

Non-Carbonate Clastic

The ultimate source of Coastal Plain sediments is obviously the Piedmont, but complications are present when the actual sedimentary history of these clastics is examined. Undoubtedly much of the finer grain sizes 0.125 and 0.177 mms. came directly into the environment through the transportation properties of the main rivers, but much as well was eroded from the adjacent Coastal Plain mainland. Examination of samples taken from the Sunderland formation (Pleistocene) immediately west of the beach facies reveals that the necessary sizes are abundantly present, although not nearly as well sorted, and undoubtedly this material supplied much of the necessary grains in the beach environment. Further work being carried out on sediments around the Santee-Cooper reservoir will undoubtedly reveal some interesting data concerning transportation into the environments of sediments derived directly from the Piedmont.

Carbonate Clastic

One of the most frustrating properties of these deposits is the surficial lack of fossils within the environment. None to date have been noted within the samples herein reported, nor within approximately 150 other samples being processed. Four power auger holes have been drilled through Wicomico bar deposits into older formations beneath. In one of these, small calcareous shell fragments were noted, and other holes are planned to study the fauna. It appears likely that the long exposure and the porosity of these sediments, has resulted in total leaching of carbonate clastics over much of the area; but this is a tenuous conclusion, which only future work will answer.

ECONOMIC GEOLOGY

Environmental conditions necessary for the formation of these Pleistocene deposits were undoubtedly very similar

TO THOSE PRESENT TODAY ALONG THE SOUTH CAROLINA COAST. HEAVY MINERAL DEPOSITS HAVE BEEN FOUND ON BULL ISLAND, CAPERS ISLAND, ISLE OF PALMS, EDISTO ISLAND, FRIPP ISLAND, DEWEES ISLAND, AND HILTON HEAD ISLAND (McCAULEY, C. K., 1960, P. 1). THE POSSIBILITY OF HEAVY MINERAL DEPOSITS ASSOCIATED WITH WICOMICO SHORELINE FEATURES UNDOUBTEDLY EXISTS. SAND FOR AGGREGATE AND FILLER IS ABUNDANTLY PRESENT, CLEAN, FINE-GRAINED, AND VERY WELL SORTED. IN THE BAR FACIES, ONLY ABOUT 2% OF THE SEDIMENTS LIE WITHIN THE CLAY-SILT FRACTION, 86% OF THE TOTAL SAMPLE OCCURRING BETWEEN 0.250 AND 0.177 MMS.

LAND USE WITHIN THE AREA IS REFLECTIVE OF THE UNDERLYING SUBSTRATA. FARMING IS CARRIED OUT EXTENSIVELY ON THE BEACH AND LAGOON AREAS EXCEPT WHERE THE WATER TABLE INTERSECTS THE SURFACE TO DEVELOP EXTENSIVE SWAMPS. SOME OF THE BAR AND MUCH OF THE SHELF IS LARGELY DEVOTED TO EXTENSIVE TREE FARMING WITHIN THE AREA STUDIED.

CONCLUSIONS

ASIDE FROM PHYSIOGRAPHIC EVIDENCE CONCERNING THE EXISTENCE OF THE WICOMICO SHORELINE, DATA MADE APPARENT THROUGH THE FIELDS OF SEDIMENTARY PETROLOGY AND SEDIMENTATION ARE ABUNDANTLY PRESENT.

PRELIMINARY EVIDENCE HAVING BEEN PRESENTED, DEFINITION OF THE VARIOUS PLEISTOCENE SHORELINES IN THE SOUTH CAROLINA COASTAL PLAIN IS BEING CONTINUED. OTHER ENVIRONMENTS ARE PRESENT, BOTH DELTAIC AND ESTUARINE. GENERAL SURFACE GEOLOGIC MAPPING, DETAILED STUDY OF GRAIN-SIZE DISTRIBUTION, AND MINERALOGICAL EXAMINATION OF SEDIMENTS IS CONTINUING WITH A VIEW TO ESTABLISHING ENVIRONMENTAL CONDITIONS OF DEPOSITION, MINERAL STABILITY, AND PROVENANCE OF ASSOCIATED SEDIMENTS. IT IS HOPED THAT FUTURE WORK WILL OUTLINE ASSOCIATED FAUNAS.

REFERENCES CITED

COOKE, C. W., 1930, CORRELATION OF COASTAL TERRACES: JOUR. GEOL., V. 38, PP. 577-589.

_____ 1936, GEOLOGY OF THE COASTAL PLAIN OF SOUTH CAROLINA: U. S. GEOL. SURVEY BULL. 867.

DOERING, J. A., 1960, QUATERNARY SURFACE FORMATIONS OF THE SOUTHERN PART OF THE ATLANTIC COASTAL PLAIN: JOUR. GEOL, V. 68, NO. 2, PP. 182-202.

DUBAR, J., 1959, THE WACCAMAW AND CROATAN DEPOSITS OF THE CAROLINAS: S. C. STATE DEV. BD., DIVISION OF GEOLOGY, GEOLOGIC NOTES, V. 3, NO. 6, PP. 1-9.

FLINT, R. F., 1940, PLEISTOCENE FEATURES OF THE ATLANTIC COASTAL PLAIN: AMER. JOUR. SCI., V. 238, PP. 757-787.

MACNEIL, F. S., 1950, PLEISTOCENE SHORELINES IN FLORIDA AND GEORGIA: U. S. GEOL. SURVEY PROF. PAPER 221-F, PP. 91-107.

McCauley, C. K., 1960, Exploration for heavy minerals on Hilton Head Island, South Carolina: S. C. State Dev. Bd., Division of Geology, Bull. 26, pp. 1-13.
Pettijohn, F. J., 1957, Sedimentary Rocks: Harper & Brothers, New York.
Richards, H. G., 1943, Pliocene and Pleistocene mollusks from the Santee-Cooper area, South Carolina: Acad. Nat. Sci. Not. Nat. 118.
_____ 1945, Subsurface stratigraphy of the Atlantic Coastal Plain between New Jersey and Georgia: Amer. Assoc. Petrol. Geol. Bull., v. 29, pp. 885-955.
_____ 1945, Correlation of Atlantic Coastal Plain Cenozoic formations, a discussion: Geol. Society Amer. Bull., v. 56, pp. 401-408.
_____ 1950, Geology of the Coastal Plain of North Carolina: Trans. Amer. Philos. Soc., v. 40, pt. 1, pp. 1-83.
_____ 1954, The Pleistocene of Georgia: Georgia Mineral Newsletter, v. 7, pp. 110-114.
_____ 1956, The marine Pleistocene of eastern North America: Actes du IV Congres International du Quaternaire, Rome, pp. 526-528.
_____ 1959, Recent studies on the Pleistocene of the South Atlantic Coastal Plain: Southeastern Geology, v. 1, no. 1, pp. 11-21.
Shattuck, G. B., 1901, The Pleistocene problem of the North Atlantic Coastal Plain: Johns Hopkins University Circular No. 152.
Sloan, E., 1908, Catalogue of the mineral localities of South Carolina: South Carolina Geol. Survey, Ser. IV, Bull. 2, (reprinted 1958, State Development Board, Division of Geology).

PIEZOMETRIC LEVELS IN THE CRETACEOUS SAND AQUIFER OF THE SAVANNAH RIVER BASIN 1/

By

George E. Siple 2/

INTRODUCTION

A program of ground-water investigation for the U. S. Atomic Energy Commission at its Savannah River Plant was conducted by the South Carolina District of the U. S. Geological Survey during the period 1952-1955. The area principally investigated was on the South Carolina side of the Savannah River but the geologic and hydrologic factors prevailing on the Georgia side of the river and contiguous to the plant site were likewise of fundamental concern. The area extends generally along both sides of the river about 40 miles southeast from Augusta. A report on the entire investigation has been released to the open file. This paper treats principally of one hydrologic phase of the study — the piezometric surface of the principal sand aquifer.

STRATIGRAPHY

The area lies entirely within the Coastal Plain province and extends southeast from the Fall Line. It is underlain by unconsolidated to partly consolidated sedimentary rocks consisting of sand, clay, marl and gravel of Late Cretaceous to recent age. Deposits of Tertiary age overlap the Cretaceous rocks in most of the area and extend northwestward as a thin cover over the crystalline rocks of the Piedmont. The Coastal Plain formations have a monoclinal structure and strike northeast-southwest with a dip to the southeast of from 6 to 20 feet per mile. A generalized stratigraphic section in the central part of the area shows about 30 feet of the Hawthorn formation of Miocene age at the land surface, underlain by 70 feet of the Barnwell formation of late Eocene (Jackson) age, 200 feet of the McBean formation of middle Eocene (Claiborne) age, 80 feet of deposits of Late Cretaceous age (equivalent to the Blufftown formation of western Georgia), and 600 feet of the Tuscaloosa formation, the basal unit of Late Cretaceous age. Underlying these sedimentary rocks is a crystalline-rock complex including granite, chlorite- hornblende schist, and gneiss. These rocks are generally considered to be an extension of those of the Piedmont to the northwest. Locally above the Tertiary formations are the Pleistocene terrace deposits, which occur below altitudes of

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2/ District Geologist, Columbia, S. C. Publication authorized by the Director, U. S. Geological Survey. Prepared in cooperation with the U. S. Atomic Energy Commission.

270 FEET IN THE MAJOR AND SOME TRIBUTARY STREAM VALLEYS. THE VALIDITY OF SOME OF THE HIGHER TERRACES AS REPRESENTATIVE MARINE FEATURES HAS BEEN QUESTIONED BY SEVERAL GEOLOGISTS, WHO MAINTAIN THAT THOSE ABOVE 100 FEET SHOW NO RECOGNIZABLE MARINE CRITERIA AND THEREFORE ARE OF AN ALLUVIAL ORIGIN. ALLUVIAL FILL OF RECENT AGE IS DISTRIBUTED IRREGULARLY OVER THE FLOOD PLAINS OF THE STREAMS THROUGHOUT THE AREA.

THE PRINCIPAL SAND AQUIFER OF LATE CRETACEOUS AGE IS REFERRED TO THE TUSCALOOSA FORMATION, ALTHOUGH SOME QUESTION EXISTS AS TO HOW MUCH OF THE SAND AND CLAY SECTION BELOW THE BEDS OF THE CLAIBORNE CAN BE CORRELATED WITH THE TUSCALOOSA. THE WRITER CONSIDERS THE BEDS OF DARK-GRAY SANDY CLAY IMMEDIATELY UNDERLYING THE CLAIBORNE GROUP TO BE OF TAYLOR OR EUTAW AGE, LARGELY ON THE BASIS OF THEIR LITHOLOGY (DARK-GRAY CLAYS, GYPSIFEROUS) AND THE CHEMICAL CHARACTER OF THEIR GROUND WATER (PREDOMINANCE OF CALCIUM AND SULFATE IONS). UNDERNEATH THIS UNIT ARE THE VARIEGATED CLAY AND MICACEOUS SAND AND GRAVEL TYPICAL OF THE TUSCALOOSA FORMATION IN THE OUTCROP AREA. EARGLE (1955, P. 8) BELIEVES THAT THE TUSCALOOSA FORMATION THINS EASTWARD FROM MACON COUNTY AND SUGGESTS THAT ITS TOTAL THICKNESS IN EASTERN GEORGIA IS ONLY ABOUT 30 FEET. THE FORMATION AS HERE DESCRIBED, 25 MILES SOUTHEAST OF AUGUSTA, IS MORE THAN 600 FEET THICK. THE THICKNESS OF THE SEDIMENTS THOUGHT BY THE WRITER TO BE OF TAYLOR TO EUTAW AGE RARELY EXCEEDS 100 FEET. CONCEIVABLY PART OF THE REMAINDER REPRESENTS POST-TUSCALOOSA DEPOSITS OF LATE CRETACEOUS AGE, BUT UNLESS THE BASAL SANDS AND CLAYS IN THE OUTCROP AREA (EXTENDING ACROSS AIKEN AND RICHMOND COUNTIES) WHICH ARE NOW REFERRED TO THE TUSCALOOSA CAN BE SHOWN TO BE YOUNGER, IT SEEMS UNLIKELY THAT ANY APPRECIABLE PERCENTAGE OF THIS BURIED INTERVAL CAN BE CONSIDERED YOUNGER THAN TUSCALOOSA. THE LITHOLOGY OF THE SEDIMENTS OVERLYING THE BASEMENT ROCK IS TYPICAL OF TUSCALOOSA BEDS ELSEWHERE BUT THE EVIDENCE FROM FOSSILS IS INCONCLUSIVE, TO DATE FURNISHED ONLY BY FOSSIL PLANTS SOME OF WHICH RANGE INTO POST-TUSCALOOSA TIME.

THERE ARE SOME INDICATIONS THAT THE SAVANNAH RIVER BASIN HAS BEEN DOWN-WARPED WITH STRUCTURALLY HIGHER AREAS IN ADJACENT GEORGIA AND SOUTH CAROLINA. IF THIS IS TRUE IT WOULD FACILITATE THE ACCUMULATION OF A THICKER AND MORE COMPLETE SUCCESSION OF CRETACEOUS UNITS IN THE BASIN AREA.

REGARDLESS OF ITS SUBDIVISION WITHIN THIS AGE, THE PRINCIPAL SAND AQUIFER IS OF LATE CRETACEOUS AGE AND CONSISTS OF A FINE TO GRAVELLY ARKOSIC SAND WITH IRREGULAR LENSES OF GRAY, WHITE, BUFF, AND PURPLE CLAY. LENTICULAR PODS OF KAOLIN OCCUR ALONG A ZONE PARALLELING THE STRIKE AND GENERALLY WITHIN 2 TO 10 MILES OF THE FALL LINE. THESE DEPOSITS ARE MINED PRINCIPALLY IN AN AREA EAST OF MACON IN CENTRAL GEORGIA AND IN THE VICINITY OF AIKEN, SOUTH CAROLINA.

HYDROLOGIC FACTORS

Ground water in the area occurs under both water-table and artesian conditions. Under water-table conditions the surface of the saturated zone is unconfined (under atmospheric pressure) and free to rise and fall in a vertical direction. Under artesian conditions, the water in the aquifer is confined below relatively impermeable beds and hydrostatic pressure causes the water to rise above the bottom of the confining bed when the aquifer is penetrated by a well. Water in the shallow aquifer (within about 100 feet of ground surface) almost always occurs under water-table conditions, whereas water in the deeper aquifers is usually artesian.

The Cretaceous deposits crop out in the northern and western parts of Aiken County where they were exposed by erosion of the overlying Tertiary beds, and in some areas to the northeast where possibly no Tertiary overlap occurred. Generally in these outcrop areas the ground water occurs under water-table conditions. Some exceptions were noted in topographically low areas, such as in the valley of Shaw Creek, where clay lenses in the Cretaceous beds or a slumped cover of Tertiary clays function as a confining bed for water in the underlying Cretaceous sands and artesian conditions prevail.

Farther down the dip, where the Cretaceous beds are more deeply covered with the Tertiary deposits, artesian conditions prevail in all but the topmost sands.

PIEZOMETRIC SURFACE

The piezometric surface of water in an artesian aquifer is an imaginary surface that represents the height to which water will rise in tightly cased wells that tap the aquifer. This surface may be represented by a piezometric map on which isopiestic lines represent the pressure surface in much the same manner as contour lines represent the ground surface on a topographic map.

The piezometric map is used to interpret not only hydrologic factors but also geologic factors. It indicates the recharge and discharge areas of an aquifer and the direction of movement of the confined water. Areas of high hydrostatic pressure on the piezometric map represent areas of recharge to the aquifer whereas areas of low pressure indicate discharge areas. The direction of ground-water movement is normal to the piezometric contour, and proceeds from points of high head to those of lower head. Figure 1 is a contour map having isopiestic lines representing the head in the principal sand aquifer of Late Cretaceous age in parts of Richmond and Burke Counties, Georgia, and Aiken and Barnwell

COUNTIES, SOUTH CAROLINA. THE WATER LEVELS IN WELLS ON THE GEORGIA SIDE WERE OBTAINED PRINCIPALLY FROM BULLETIN 64 OF THE GEORGIA DEPARTMENT OF MINES, MINING, AND GEOLOGY. THE TOPOGRAPHICALLY HIGH AREA, USUALLY CAPPED BY TERTIARY DEPOSITS AND LOCATED EAST OF AIKEN AND SOUTHWEST OF AUGUSTA, REPRESENT AREAS OF RECHARGE TO THE AQUIFER AND ARE REPRESENTED BY PIEZOMETRIC HIGHS ON THE MAP. THE PRONOUNCED DEPRESSION IN THE PIEZOMETRIC SURFACE NEAR THE SAVANNAH RIVER, DOWNSTREAM FROM AUGUSTA AND ALONG LOWER HORSE CREEK INDICATES THAT THE AQUIFER IS DISCHARGING WATER INTO HORSE CREEK AND INTO THE SAVANNAH RIVER FROM NEAR AUGUSTA, DOWNSTREAM TO THE VICINITY OF THE AIKEN-BARNWELL COUNTY LINE. THIS AREA IS INDICATED ON THE MAP AS EXTENDING SOUTHEASTWARD TO ABOUT THE AIKEN-BARNWELL COUNTY LINE. THE DATA ARE INCOMPLETE BEYOND THAT POINT BUT AT SOME PLACE DOWNSTREAM THE PIEZOMETRIC GRADIENT WILL REVERSE AND SHOW A GRADUAL DECLINE IN THE SOUTHEASTWARD OR COASTAL DIRECTION. THIS POSTULATES THE PRESENCE OF A "SADDLE" ON THE PIEZOMETRIC SURFACE, JUST SOUTH OF THE DISCHARGE AREA. THE AUTHOR SUGGESTS THAT THIS PARTICULAR HYDROLOGIC CONDITION, IDENTIFIED HERE ON THE SAVANNAH RIVER SYSTEM, IS ALSO CHARACTERISTIC OF HYDROLOGIC CONDITIONS ON OTHER LARGE STREAMS CROSSING THE CRETACEOUS OUTCROP AREAS ALONG THE ATLANTIC COASTAL PLAIN.

IT IS RECOGNIZED THAT THE DATA REPRESENTED ABOVE ARE NOT SUFFICIENTLY COMPLETE TO PROVE CONCLUSIVELY THAT THE DISCHARGE AREA IS DELINEATED BY CLOSED CONTOURS ON THE DOWNRIVER SIDE. ANOTHER POSSIBILITY IS THAT THE DATA INDICATE A STEEP AND NARROW GORGE ON THE PIEZOMETRIC SURFACE, RUNNING ALMOST PARALLEL TO THE RIVER FOR A DISTANCE OF 30-40 MILES. HOWEVER, CONSIDERING THE NORMAL PATTERN OF GROUND-WATER FLOW IN AREAS CONTIGUOUS TO THESE EFFLUENT STREAMS, THIS CONDITION APPEARS UNLIKELY.

AFTER HAVING MAPPED THE OUTCROP AREA OF THE CRETACEOUS SAND FORMATION THE AUTHOR RECOGNIZED THAT CONTRARY TO SOME ILLUSTRATIONS OF ARTESIAN CONDITIONS, THE OUTCROP AREA OF THE AQUIFER FUNCTIONS MORE AS A DISCHARGE AREA THAN IT DOES AS A RECHARGE AREA.

IN ADDITION TO ITS HYDROLOGIC SIGNIFICANCE THE PIEZOMETRIC MAP ALSO CONTRIBUTES TO OUR KNOWLEDGE OF THE GEOLOGIC HISTORY OF THE AREA. AS ONE WOULD EXPECT, IN THE NORTHERN PART OF THIS DEPRESSION WHERE THE RIVER CROSSES THE OUTCROP OF LATE CRETACEOUS SANDS (TUSCALOOSA FORMATION AND POSSIBLY OTHER SANDS APPROXIMATELY TAYLOR IN AGE), GROUND WATER DISCHARGES INTO THE RIVER VERY READILY. NEAR THE SOUTHERN END OF THE DEPRESSION ONE WOULD EXPECT THE OVERLYING CLAY WOULD PREVENT ANY GROUND-WATER DISCHARGE; HOWEVER, THE RIVER MUST HAVE CUT THROUGH THE CONFINING CLAYS INTO THE AQUIFER, PROBABLY SOMETIME DURING THE PLEISTOCENE EPOCH WHEN THE SEA LEVEL WAS AT LEAST 200 FEET LOWER THAN IT IS NOW, AND THE RIVER'S ADJUST-

MENT TO THE CHANGE IN GRADIENT ALLOWED DOWNCUTTING IN THE UPPER REACHES. SUBSEQUENTLY THE ERODED VALLEY WAS FILLED WITH PERMEABLE MATERIAL, WHICH NOW PERMITS WATER FROM THE TUSCALOOSA FORMATION TO MOVE UPWARD AND DISCHARGE INTO THE RIVER.

IN FIGURE 1, THE 360-FOOT ISOPIESTIC LINE AT AIKEN IS ABOUT 14 MILES NORTHEAST OF THE 160-FOOT LINE NEAR THE SAVANNAH RIVER. THE DIFFERENCE IN HEAD REPRESENTED BY THE TWO LINES IS 200 FEET; HENCE, THE GRADIENT IS ABOUT 14 FEET PER MILE. THE AVERAGE COEFFICIENT OF TRANSMISSIBILITY OF THE PRINCIPAL SAND AQUIFER IS ABOUT 200,000 ON THE BASIS OF SEVERAL PUMPING TESTS. THUS 200,000 X 14 OR ABOUT 2.8 MILLION GALLONS PER DAY (MGD) DISCHARGES THROUGH EACH 1-MILE STRIP OF THE AQUIFER MEASURED ALONG THE 160-FOOT CONTOUR LINE. THIS REPRESENTS A TOTAL DISCHARGE OF ABOUT 85 MGD FROM EACH SIDE OF THE RIVER ACROSS THIS CONTOUR. THIS FIGURE CAN BE COMPARED WITH THE MEASURED DISCHARGE OF THE SAVANNAH RIVER BOTH ABOVE AND BELOW THE PIEZOMETRIC LOW INDICATED ON THE MAP. THE AVERAGE DISCHARGE AT AUGUSTA FOR THE WATER YEAR 1954-55 AS REPORTED BY THE SURFACE WATER BRANCH OF THE U. S. GEOLOGICAL SURVEY (1956, P. 270-1) AMOUNTED TO 5,487 CFS; THAT AT MILLHAVEN, GEORGIA, DOWNSTREAM WAS 6,052 CFS FOR THE SAME PERIOD. THIS REPRESENTS AN INCREASE OF 565 CFS. TRIBUTARY STREAMS SUCH AS MCBEAN CREEK, UPPER THREE RUNS, LOWER THREE RUNS AND OTHER SMALLER STREAMS ARE ESTIMATED TO CONTRIBUTE ABOUT 265 CFS, LEAVING A NET INCREASE OF ABOUT 300 CFS (194 MILLION GALLONS PER DAY) OR 1.1 TIMES THE AMOUNT CALCULATED AS ACCRETION FROM THE AQUIFER. THESE FIGURES, OF COURSE, ARE ROUGH BUT THEY DO INDICATE THE GENERAL MAGNITUDE OF THE GROUNDWATER DISCHARGE IN THIS AREA.

THE HYDROSTATIC HEAD OF WATER IN THE PRINCIPAL SAND AQUIFER RANGES FROM A HIGH OF 380 FEET IN UPPER AIKEN AND RICHMOND COUNTIES DOWN TO APPROXIMATELY 124 FEET IN LOWER BEAUFORT COUNTY ON THE ATLANTIC COAST. THE DISTANCE BETWEEN THE TWO AREAS IS ABOUT 100 MILES AND THUS THE AVERAGE GRADIENT OF THE WATER IN THE PRINCIPAL SAND AQUIFER IS 2.5 FEET PER MILE ACROSS THE ENTIRE COASTAL PLAIN IN THE SAVANNAH RIVER AREA.

IT IS INTERESTING TO NOTE THAT EXCEPT FOR THE DEEP WELL NEAR PARRIS ISLAND, S. C., THERE IS NO UTILIZATION OF THE AQUIFER IN THE TUSCALOOSA FORMATION BETWEEN THE UPPER COASTAL PLAIN AND THE COAST. THE REASON IS PROBABLY ECONOMIC — IT IS MORE EXPENSIVE TO DRILL TO DEEPER AQUIFERS WHEN SUFFICIENT QUANTITIES OF SATISFACTORY QUALITY CAN BE OBTAINED AT SHALLOWER DEPTHS. HOWEVER, THE WATER IN THE TUSCALOOSA HAS A LOWER FLUORIDE CONTENT AND IN MOST PLACES LOWER CHLORIDE CONTENT THAN THE WATER FROM THE SHALLOWER AQUIFERS. ITS RELATIVELY HIGH TEMPERATURE IN COASTAL AREAS (104^{0}-107^{0}F) CONSTITUTES A POSSIBLE DISADVANTAGE FOR ORDINARY DRINKING PURPOSES BUT COULD CONCEIVABLY BE ADVANTAGEOUS FOR CERTAIN INDUSTRIAL USES.

THE HIGHER HEAD OF THE WATER IN THE TUSCALOOSA IN AREAS BETWEEN THE COAST AND THE FALL LINE CONSTITUTES A DEFINITE ADVANTAGE.

THE POSITION OF THE PIEZOMETRIC SURFACE AS INDICATED IN FIGURE 1 REPRESENTS THE PREVAILING PRESSURE CONDITIONS DUE ALMOST ENTIRELY TO NATURAL DISCHARGE, THERE BEING COMPARATIVELY LITTLE MANMADE DISCHARGE OF THE AQUIFER BY PUMPAGE. HOWEVER, THIS EQUILIBRIUM CONDITION WILL BE AFFECTED BOTH BY NATURAL AND CULTURAL CHANGES SO THAT SUBSEQUENT STAGES OF THE PIEZOMETRIC SURFACE WILL SHOW DEVIATIONS TO THE EXTENT THAT THESE CHANGES IN DISCHARGE OR RECHARGE AFFECT THE AQUIFER.

THE MOST PRONOUNCED EFFECT ON THE PIEZOMETRIC SURFACE IS THAT BROUGHT ABOUT BY PUMPING. VARIATIONS IN PRECIPITATION, EVAPOTRANSPIRATION AND ATMOSPHERIC PRESSURE ALSO PRODUCE CHANGES IN WATER LEVEL. PRECIPITATION CAN BE CORRELATED MORE DIRECTLY WITH WATER-LEVEL CHANGES IN WATER-TABLE WELLS ALTHOUGH ITS EFFECT IS RECOGNIZED INDIRECTLY IN ARTESIAN WELLS ALSO. THE ELASTIC NATURE OF THE ARTESIAN AQUIFER ALLOWS A CONTRACTION OR EXPANSION TO FOLLOW THE APPLICATION OR RELEASE OF EXTERNAL FORCES. THUS, SUCH LOADING FORCES AS OCEANIC OR EARTH TIDES, PASSING RAILROAD TRAINS OR CHANGES IN STREAM STAGE CAUSE DEFORMATION OF THE ARTESIAN AQUIFER WITH A RESULTANT TEMPORARY CHANGE IN WATER LEVELS. EARTHQUAKES ARE KNOWN TO AFFECT WATER LEVELS IN WELLS IN MANY PARTS OF THE WORLD.

IN ARTESIAN WELLS UNAFFECTED BY PUMPING, ONE OF THE PRINCIPAL CAUSES OF WATER-LEVEL FLUCTUATION IS THE DAILY VARIATION IN ATMOSPHERIC PRESSURE. AN INCREASE IN AIR PRESSURE IS TRANSMITTED DIRECTLY TO THE WATER SURFACE INTHE WELL BUT IS BALANCED AGAINST A LESSER PRESSURE COMING THROUGH THE AQUIFER TO THE WELL SCREEN, WITH A RESULTANT DROP IN WATER LEVEL. THE RATIO OF THE WATER LEVEL CHANGE IN A WELL TO THAT OF THE ATMOSPHERIC PRESSURE (EXPRESSED IN CONVERTIBLE UNITS) IS REFERRED TO AS THE "BAROMETRIC EFFICIENCY" OF THE WELL. OBSERVATIONS OF THE WATER-LEVEL FLUCTUATIONS IN SEVERAL WELLS IN THE AUGUSTA-AIKEN AREA THAT WERE CAUSED BY CHANGES IN ATMOSPHERIC PRESSURE INDICATE VALUES OF APPROXIMATELY 33 TO 35 PERCENT FOR THE BAROMETRIC EFFICIENCY.

SIMILARLY THE RATIO OF WATER-LEVEL CHANGE IN A WELL NEAR THE COAST TO THE RANGE OF THE TIDE AS OBSERVED AT THE COAST IS REFERRED TO AS THE "TIDAL EFFICIENCY." THE SUM OF THE BAROMETRIC EFFICIENCY AND THE TIDAL EFFICIENCY IS UNITY.

THUS, SEVERAL FACTORS MAY INDIVIDUALLY OR COLLECTIVELY EFFECT A CHANGE IN THE PIEZOMETRIC SURFACE. ON THE SOUTH CAROLINA SIDE OF THE AREA THE NET CHANGE IN WATER LEVEL OR PIEZOMETRIC SURFACE SINCE 1954 WHEN THE MAP ON FIGURE 1 WAS COMPILED, IS ESTIMATED NOW (DECEMBER 1959) TO RANGE FROM 2 TO 7 FEET LOWER AS DETERMINED FROM SCATTERED WATER LEVEL MEASURE-

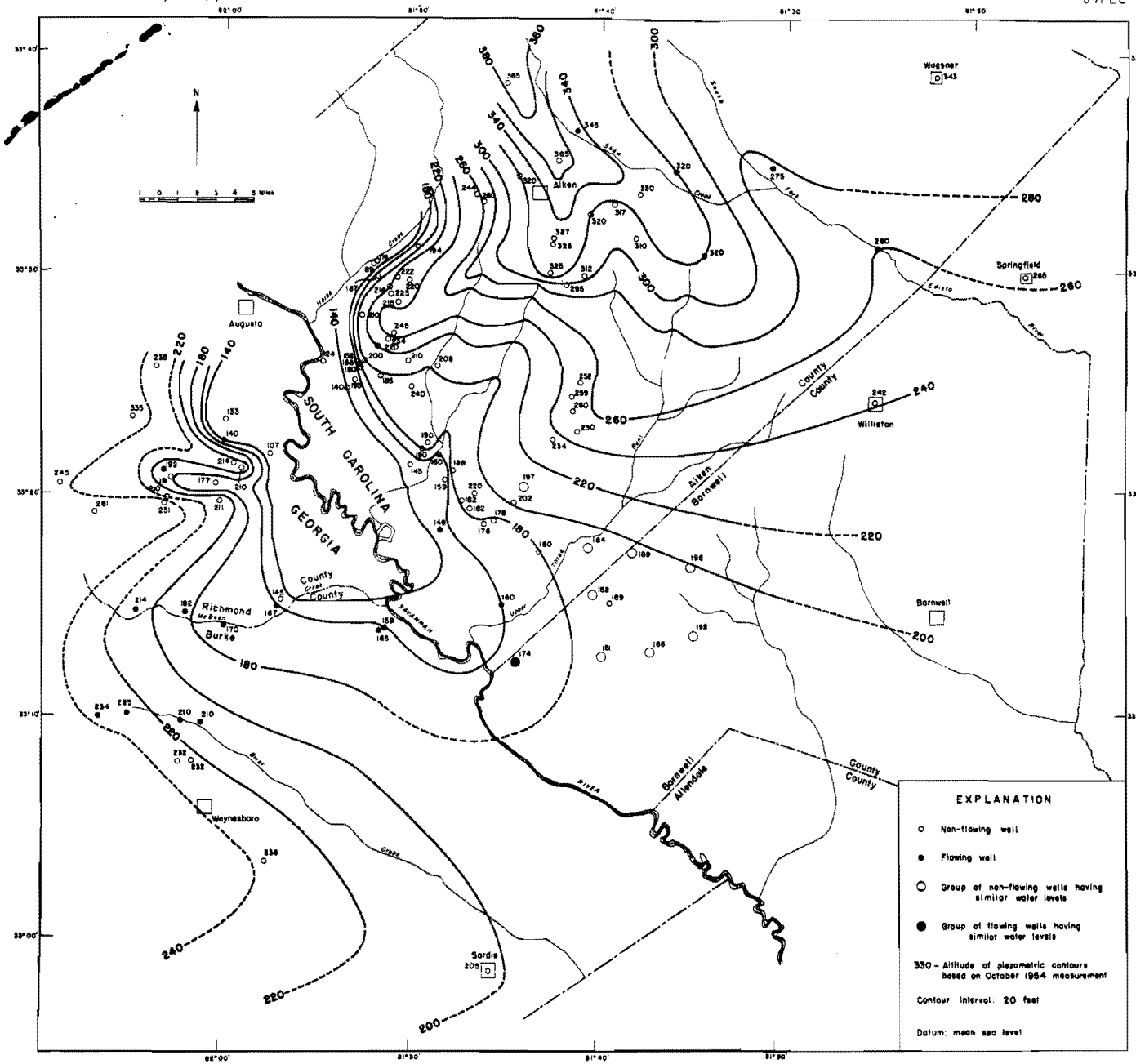

Figure 1.—Piezometric map of the principal sand aquifer of late Cretaceous (Tuscaloosa) age.

MENTS AND AUTOMATIC RECORDING GAGES. THIS CHANGE IS DUE IN LARGE PART TO AN ESTIMATED WITHDRAWAL OF ABOUT 10 MILLION GALLONS PER DAY FOR INDUSTRIAL AND MUNICIPAL PURPOSES. THE NET CHANGE IN THE PIEZOMETRIC SURFACE ON THE GEORGIA SIDE HAS NOT BEEN DETERMINED.

ANOTHER FACTOR WHICH HAS CONSIDERABLE INFLUENCE ON RECENT PIEZOMETRIC CHANGES IS THE RAINFALL FREQUENCY DURING THE PERIOD 1952-59. DURING 1952-57 THERE WERE SEVERAL YEARS OF DROUGHT AND A GENERAL DECLINE IN WATER LEVELS IN ALL WELLS THROUGHOUT THE PERIOD OCCURRED. THE HIGH RATE OF RAINFALL DURING 1958 AND 1959 HAS REVERSED THIS DOWNWARD TREND OF WATER LEVELS AND THEY HAVE RECOVERED TO THEIR PRESENT STAGE.

CONTINUING OR PERIODIC ADDITIONAL STUDIES ARE NEEDED ON BOTH SIDES OF THE SAVANNAH RIVER TO ASCERTAIN MORE ACCURATELY THE NET EFFECT ON THE PIEZOMETRIC LEVELS OF CHANGES IN PUMPING. THESE SUPPLEMENTARY STUDIES WOULD TEND TO ELIMINATE UNDUE EMPHASIS UPON THE EFFECT OF ERRATIC RAINFALL PATTERNS, BUT MORE SIGNIFICANTLY THEY WOULD PROVIDE A BASIS FOR THE WISE MANAGEMENT OF THE IMPORTANT WATER RESOURCES AVAILABLE FROM THE AQUIFERS OF THIS AREA.

REFERENCES

EARGLE, D. H., 1955, STRATIGRAPHY OF THE OUTCROPPING CRETACEOUS ROCKS OF GEORGIA: U. S. GEOL. SURVEY BULL. 1014, 101 P.

LEGRAND, H. E., AND FURCRON, A. S., 1956, GEOLOGY AND GROUNDWATER RESOURCES OF CENTRAL-EAST GEORGIA: GEORGIA GEOL. SURVEY BULL. 64, 174 P.

SURFACE WATER SUPPLY OF THE UNITED STATES, 1955, PART 2-A, SOUTH ATLANTIC SLOPE BASINS, JAMES RIVER TO SAVANNAH RIVER, U. S. GEOL. SURVEY WATER-SUPPLY PAPER 1333, 1956, 314 P.

ERRATA

THE FOLLOWING ADDITIONS AND CORRECTIONS SHOULD BE MADE IN THE JULY-AUGUST 1961 ISSUE OF GEOLOGIC NOTES:

(1) FOLLOWING PAGE 44. -- THE SCALE OF FIGURE 1 IS 1" = 1.97 MI.
(2) PAGES 43-50. -- FOR MEAN SIZE, READ MEDIAN DIAMETER. FOR CLAY, READ CLAY AND SILT.
(3) PAGE 45, LINE 30. -- FOR 4.5, READ 0.8.
(4) PAGE 45, LINE 36. -- FOR AND, READ TO.
(5) PAGE 45, LINE 43. -- FOR THE SENTENCE BEGINNING KURTOSIS, READ KURTOSIS VALUES ARE APPROXIMATELY 0.25.
(6) PAGE 46, LINE 15. -- SENTENCE SHOULD READ SKEWNESS DECREASES FROM APPROXIMATELY 1.4 TO ABOUT 1.00.
(7) PAGE 46, LINE 16. -- FOR THE SENTENCE BEGINNING THE KURTOSIS, READ KURTOSIS RANGES FROM 0.11 TO 0.21.
(8) FOLLOWING PAGE 46, FIGURE 3.--FOR BEACH FACIES, CHANGE SKEWNESS TO 0.8, KURTOSIS TO 0.25. FOR LAGOON FACIES, CHANGE SKEWNESS TO 1.0, KURTOSIS TO 0.21.
(9) NOTE. -- ALL SAMPLES WERE DRY SIEVED.